Remote Access Information System for Analysis of Chemical Engineering Objects

V.A. Nemtinov [1], Yu.V. Nemtinova[2], A.A. Pchelinzeva[3], A.M. Manaenkov[4]

Department of Computer-aided Design of Processing Equipment, Tambov State Technical University
106, Sovetskaya street, Tambov, Russia

[1]nemtinov@mail.gaps.tstu.ru; [2]jnemtinova@hotmail.com; [3]p4elintseva.anuta@yandex.ru; [4]tonik1987@mail.ru

Abstract

This article describes basic design steps of a remote access information system for analysis of chemical engineering objects using various technologies: simulation modeling, geographic information systems (GIS), Internet technologies, etc.

Base system used for design of a virtual model is GIS which allows creating spatial models of enterprises including all major production facilities. There are three information fields, each of which displays its own information type: a two-dimensional (three-dimensional) model of an enterprise; a simulation model of technological processes of an enterprise, a textual reference with production procedures.

Keywords

Models of Chemical Engineering Objects; Geographic Information System; Internet Technologies; Simulation Modeling System

Introduction

Traditional means of describing chemical engineering objects represent them in the form of process flow diagrams, drawings of equipment and its elements. But the most comprehensive analysis is only possible through a multilateral approach with the use of various information technologies, which allow looking beyond objects’ visual image. This problem can be solved by integrated use of different programming environments: simulation modeling systems, geographic information systems (GIS), Internet technologies, etc.

Information-logical Models of Technological Process of Chemical-technological Systems

Nowadays industrial objects are viewed as complex dynamic systems characterized with high levels of uncertainty of initial information and complexity of their behavior. Thus, simulation modeling can be used in order to find a solution to a wide range of problems associated with management of such systems, as well as to facilitate the work of operators and technicians.

In order to analyze technological processes of chemical engineering systems, it is expedient to use systems that imitate real processes.

A computer simulation model is a convenient aid for a system analyst who examines chemical engineering facilities. The main advantage of simulation is that experts can answer the question "what will happen, if ...", i.e. by conducting experiments with the model an expert can develop analysis strategy.

Information-logic models (ILM) are the core of simulation modeling; which they describe conditions of technological processes. In general, an ILM for decision-making support at chemical engineering objects’ analysis is a union of data sets and relationships between them expressed in the form of rules. Each production rule (PR) contained in the knowledge base consists of two parts: antecedent and consequent. The antecedent is a hypothesis of a rule (conditional part) and consists of elementary sentences, connected by logical connectives "and, or." Consequent (inference) consists from one or more sentences that express some fact or reference to an action to be executed.

Thus, an ILM can be represented by the following tuple:

$$\mathrm{M} = \langle D,\ P \rangle,\ \ D = (d_1, \ldots, d_i, \ldots, d_N),$$
$$P = (p_1, \ldots,\ p_j, \ldots, p_S),$$

where M - ILM operator; $d_1, \ldots, d_i, \ldots, d_N$ - ILM data set; $p_1, \ldots, p_j, \ldots, p_S$ - set of rules.

ILM rules has the following structure: if … (fulfillment of a condition), then … (execution of a consequence) and can be represented as:

$$p^{\kappa}:\left\{ if \begin{pmatrix} \left(d_1^{\kappa'} A_1\ z_1^{\kappa'}\right)\Lambda_1\left(d_2^{\kappa'}\ A_2\ z_2^{\kappa'}\right)\Lambda_2 \\ \ldots\Lambda_{n-1}\left(d_n^{\kappa'}\ A_n\ z_n^{\kappa'}\right) \end{pmatrix} \right. \\ then\ \left(d_{1m}^{\kappa\ ''}\ A_1'\ z_{1M}^{\kappa\ ''}\right)\Big\},$$

where $A_1 ... A_i, A_1' \in \{=,<,\leq,\geq,>\}$, $i=\overline{1,n'}$ - arithmetic operator; $\Lambda_i \in \{\wedge,\vee\}$ - logic operator; $d_n^{k'}, d_{1m}^{k\ ''}$ - input and output data; $Z^{\hat{e}'} = \left\{z_1^{\hat{e}'},...,z_1^{\hat{e}'}\right\}$ - set of input values ; $d_n^{k'}$; $z_1^{k''} \in \left\{z_{11}^{k\ ''},...,z_{1M}^{k\ ''}\right\}$ - output values for $d_{1m}^{k\ ''}$, *n*- number of conditions, *k*- PR index.

The use of ILM for analysis of chemical-processing objects is demonstrated on the example of determining production stages of a product depending on characteristics of its feedstock: "characteristics of raw materials and industrial products" - " production stage of a product"; followed by another example of determining the type of equipment: "production stage of a product"- "equipment type". Here we use a set of data about raw materials and industrial products S_{prod}, production stages St_{prod} and equipment $Ob_{prod.}$ (see Tables 1-5).

S_{prod} ={$S_{prod,1}$,…, $S_{prod,i}$,…, $S_{prod,I}$}, $i=\overline{1,I}$;

St_{prod} ={$St_{prod,1}$,…, $St_{prod,j}$,…, $St_{prod,J}$}, $j=\overline{1,J}$;

Ob_{prod} ={$Ob_{prod,1}$,…, $Ob_{prod,k}$,…, $Ob_{prod,K}$}, $k=\overline{1,K}$.

TABLE 1 – CHARACTERISTICS OF RAW MATERIALS AND PRODUCTS

Indicator name
$S_{prod,1}$= «alkalescent medium reaction»
$S_{prod,2}$= «mass concentration of beta-naphthol 243-245 g/dm^3»
$S_{prod,3}$= «mass concentration of sodium hydroxide 67-69 g/dm^3»
$S_{prod,4}$= «mass concentration of diluted sulfuric acid solution 170-200 g/dm^3»
$S_{prod,5}$= «mass fraction of sodium nitrite solution 25-40%»
$S_{prod,6}$= «cooled to 0°C diluted sulfuric acid solution»
$S_{prod,7}$= «mass of excess sulfuric acid 30-33 kg of 100% mass of sulfuric acid»
$S_{prod,8}$= «hydrogen ion activity index 6,5 – 7 pH»
$S_{prod,9}$= «mass fraction sodium bisulfite 22,5%,»
$S_{prod,10}$= «hydrogen ion activity index 4,4 – 4,7 pH»
$S_{prod,11}$= «alkalescent medium reaction of obtained pigment suspension on brilliant yellow paper (9,0 – 9,5 pH)»
$S_{prod,12}$= «color of a complex compound – blue»
…

TABLE 2 – PRODUCTION STAGES

Stage name
$St_{prod,1}$ = «dissolution»
$St_{prod,2}$ = «nitrosation»
$St_{prod,3}$ = «combination»
…

TABLE 3- EQUIPMENT

Equipment name
$Ob_{prod,1}$ = «reactor for preparation of beta-naphthol sodium salt»
$Ob_{prod,2}$ = «reactor for beta-naphthol nitrosation»
$Ob_{prod,3}$ = «equipment for combination stage»
…

TABLE 4 - EXAMPLES OF RULES FOR DETERMINING PRODUCTION STAGES DEPENDING ON RAW MATERIALS AND PRODUCT CHARACTERISTICS

Condition	Inference
$S_{prod,1}$ & $S_{prod,2}$ & $S_{prod,3}$ & $S_{prod,4}$ & $S_{prod,5}$	$St_{prod,1}$
$S_{prod,4}$ & S_{prod7} & $S_{prod,8}$ & $S_{prod,9}$ & $S_{prod,10}$	$St_{prod,2}$
$S_{prod,12}$ & $S_{prod,13}$ & $S_{prod,14}$	$St_{prod,3}$
…	…

For example, the first rule can be explained as:

Rule 1: if ($S_{prod,1}$= «alkalescent medium reaction») and ($S_{prod,2}$= «mass concentration of beta-naphthol 243-245 g/dm^3») and ($S_{prod,3}$= «mass concentration of sodium hydroxide 67-69 g/dm^3 67-69 g/dm^3») and ($S_{prod,4}$= «mass concentration of diluted sulfuric acid solution 170-200 g/dm^3») and ($S_{prod,5}$= «mass fraction of sodium nitrite solution 25-40%»), then the production stage is $St_{prod,1}$ = «dissolution».

TABLE 5 - EXAMPLES OF EQUIPMENT SELECTION RULES DEPENDING ON PRODUCTION STAGES

Condition	Inference
$St_{prod,1}$	$Ob_{prod,1}$
$St_{prod,2}$	$Ob_{prod,2}$
$St_{prod,3}$	$Ob_{prod,3}$
…	…

For example, the first and the second rules can be explained as:

Rule 1: if $St_{prod,1}$ = «dissolution», then equipment type is $Ob_{prod,1}$ = «reactor for preparation of beta-naphthol sodium salt».

Rule 2: if $St_{prod,2}$ = «nitrosation», then equipment type is $Ob_{prod,2}$ = «reactor for beta-naphthol nitrosation».

Implementation of an ILM with a system for modeling of dynamic processes, for example using SIMUL8, will become a tool for analysis of a chemical engineering object.

Different software types for modeling of chemical engineering facilities are integrated in use.

Nowadays geographic information systems are widely used worldwide in many fields of knowledge. This is due to the fact that GIS technologies are becoming a universal means for integration of various information technologies and construction of multi-function information and analytical systems. In our case GIS serves as a tool for building of a virtual visual image supplemented by automated information and analytical system resulting in construction of a single information space of the territory of an industrial enterprise and its spatial-temporal model. User can independently select objects (units) they wish to examine. Numerous and diverse information about an object can be obtained from information and analytical database at any time. This option can be successfully implemented by the means of Internet which can be useful for studying production processes' flow diagrams (eg. production of organic dyes) as for students in related disciplines as well as for operators in maintenance of such systems.

GIS is a base information system used for creation of a virtual model as it possesses a three-dimensional modeling tool that allows building a spatial model of an enterprise including all production units of its core products (organic dyes, additives to polymeric materials, etc.). Here user can choose any unit and find out production technology of related products.

One way to address the problem of displaying spatial models of geographically distributed sites is a technology developed by the authors which allows creating spatial models of chemical engineering facilities and building display and data exchange systems using the Internet (see Figure 1). It should be noted that its implementation is based on freeware (see table 6).

The strength of this approach is in three information fields which are used to display the data (see Figure 2). User's screen is divided into three fields of information, each of which displays its own type of information:

- two-dimensional (three dimensional) model of an enterprise with a function of thematic layers;
- simulation model of a technological process under examination;
- Textual reference with production procedures .

TABLE 6 - SOFTWARE

Name and version	Distribution terms	Official website
Openlayers 2.8 – visualization script of WMS and WFS layers on a single web-map which provides convenient s caling	Freeware	http://openlayers.org
PHP - scripting language		http://www.php.net
SIMUL8- modeling of chemical engineering systems	License agreement	http://www.simul8.com

JavaScript - OpenLayers library is used to display maps. It was recently expanded by a number of features that allowed us to use it for simple tasks as an alternative to complex geographical systems. The undeniable advantage of OpenLayers is an ability to be used by the client side as this does not overload the server. This software allows a developer to use data from different servers. For example, GoogleMaps, Yandex.Karty or other services that provide WMS (Web Map Service data can be used at lower layer and specially designed maps, markers, arbitrary raster and vector elements can be used at the top layers.

FIG. 1 3D-VIEW OF A SPATIAL MODEL OF THE ENTERPRISE'S TERRITORY

The second information field is used to display a simulation model of toperations at a chemical engineering object, developed with the use of SIMUL8.

This paper presents the technique of simulation modeling on the example of a multi-assortment chemical plant using SIMUL8 for operational management of production. The main stages of this method are: developing a digital library of technological regimes, creating graphic images of technological schemes' elements, development of a simulation model using SIMUL8.

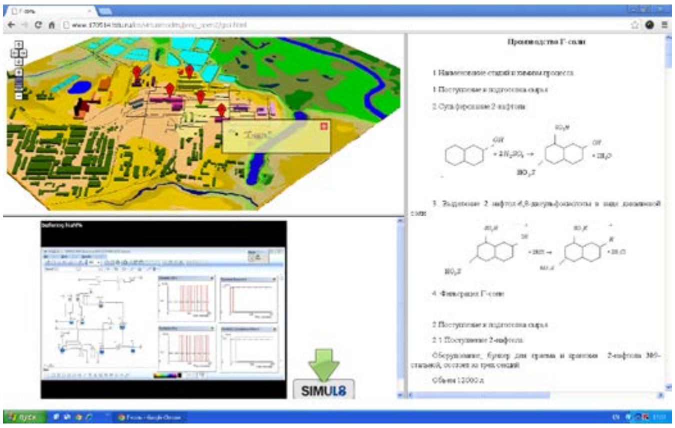

FIG. 2 THE VIEW OF USER'S SCREEN

The model reflects the production flowchart. Storages, pumps, filter-presses are modeled as "work centers". Measuring tanks, loading hoppers, dispensers are modeled as "work entry points." Unloading tanks for the finished product are "work complete point." All equipment is connected accordance to production regulations. The data for the model is obtained from: production schedules, norms of technological regimes. Each value can be set as a fixed number or a random variable with a certain distribution law.

The proposed technique of simulation modeling of chemical engineering objects with the use of SIMUL8 allowed to create the library of intermediate products and dyes: red pigment 2C, bright red pigment 4G, chrome black pigment O, varnish PF-060, 3-oxychinaldine-4-carbohylic acid, 3-oxychinophthalon, acrylic MEC, etc.

If an end user has no installed SIMUL8, he has an option to view video demonstrations of the appropriate model.

The third information field is used to generate text information. Given that the system is based on a web-server, this field id used for database support through the PHP language (a general-purpose scripting language used extensively for development of web-based applications). There is an option to search and compare attribute information about an object. An embedded html page provides the user with text information together with graphic.

The layout of these three areas of information is done by the means of frames, supported by any Internet browser. The use of frames allows the user to change the size of information areas and enlarge the regions of particular interest.

As a result we create a web-service that combines a variety of technologies, which allows obtaining detailed information about an object and to present them in the most convenient way. The base software is free of charge and has low system requirements. An obvious advantage is the ability to view web-service in the internet browser without installing additional client software, with the exception of SIMUL8.

Conclusions

The developed approach to integrated use of different software types for modeling of chemical engineering objects is implemented in the form of a teaching subsystems which is used at FGBOU VPO Tambov State Technical University in the specialty 151701 - "Design of technological machines and systems" from the list of priority areas of modernization and technological development of Russian economy [http://www.170514.tstu.ru/ios/].

REFERENCES

Egorov, S.Ya. Development of an electronic graphical reference system of technological equipment and its use in education / S.Ya. Egorov, Nemtinov V.A., V.G. Mokrozub, I.V. Milovanov // Information technologies. – 1999. – № 8. – P. 35 - 37.

Nemtinov, B.A. Prospects of using GIS-technologies in chemical industry // Chemical industry. – 2004. – № 4. –P. 8–12.

Nemtinov, V.A. Development of information reference system using INTERNET / V.A. Nemtinov, S.Ya. Egorov, V.G. Mokrozub // Information technologies. – 1999. – № 7. – P. 37 - 39.

Nemtinov, V.A. Technique of special modeling of territorially distributed objects using geo-informational systems / V.A. Nemtinov, A.M. Mananenkov, V.V. Morozov, K.V. Nemtinov // Information technologies. – 2008. – № 8. – P. 23–25.

Nemtinov, V.A. Use of a system for modeling of dynamic processes in industrial production management / V.A. Nemtinov, Yu.V. Nemtinova, D.S. Russkikh // Chemical industry today. – 2007. – № 7. – P. 43–48.

Nemtinova, Yu.V. Simulation modeling of technological processes of chemical manufacturing / Yu.V. Nemtinova, A.A. Pchelintseva, A.A. Bubnov // Transactions of Tambov State Technical University. - 2011. - №17. - P. 449-452.

Pakhomov, P.I. Geo-information model of a territory for decision making in management of utility systems / P.I. Pakhomov, V.A. Nemtinov // Transactions of Tambov State Technical University. – 2009. – № 15. – P. 199 - 207.